SYNOPSIS ON

DOPED-METAL OXIDE NANOSTRUCTURES AND THEIR BIOGENIC ACTIVITIES

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Synopsis

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1. Introduction

Microbes or micro-organisms are minute and unicellular organisms which are microscopic in nature. Few microbes are useful whereas some are harmful. The harmful micro-organisms are called pathogens. The disease-causing micro-organisms include bacteria, protozoa and few variations of worms and fungi. Human are threatened by bacteria and other micro-organisms, causing numerous pathogen related infections and illness. Antimicrobial resistance is an urgent global public health threat, killing at least 1.27 million people worldwide and associated with nearly 5 million deaths in year 2019, according to a report released in The Lancet [1]. So as to overcome this threat new strategies for fighting microbial infections are urgently required.

Nanotechnology is rapidly expanding the field of science with continuous development of nanomaterials and their applications. Nanoforms of metals, metal oxides, carbon materials and biopolymers are being used in several industries including diagnosis, drug delivery, cosmetics, food and electronics, etc. The discovery, development and clinical uses of antimicrobial materials have been a major thrust to biomedical fields because of their extensive applications for arresting microbial infections.

Antimicrobial nanomaterials classified into those that are intrinsically antimicrobial, act as carriers for antimicrobial agents and those that possess both functional properties. Although, the last decade has witnessed great progress in metal nanostructures, a thorough review is lacking in this timely research field which covers the applications and cytotoxicity of antimicrobial nanomaterials. This includes the broad range of commercially available and experimental nanometals in the biomedical field. Accordingly, the objective of the present work is to critically find the development of antimicrobial nanomaterials in biomedicine.

Research in antimicrobial nanomaterials and their biogenic applications has expanded exponentially because of the important microbicidal activities associated with these materials. There is advancement in synthesis and functionalization of nanoparticles which results in considerable increase in their biomedical applications.

The novel properties exhibited by nano metal oxides are unusual and differ from those of their bulk materials. Recently, research on ferrite nanomaterials has been shifted towards developing nanometric scales because of their wide range applications in many fields [2].

Doping means intentional introduction of some foreign elements in the vacant crystal lattice of another element with the intention of modifying their properties. In nanoparticles, the addition of a few defect atoms can make the particle highly doped. Doped nanoparticles exhibit improved properties and can be employed for various purposes. Doped nanoparticles have wide and variety of applications ranging from photo-catalysis to biomedicine.

2. Literature Review

Nanotechnology has worldwide applications in different areas including biomedical science, physics, chemistry, material sciences, electronics, and optics. The transition metal-based ferrite nanostructures avail unique structural, electrical, thermal, and magnetic characteristics are utilized for various types of engineering and biomedical applications [3]. Nanostructures of ferrites are being used in different biological applications such as X-ray diagnosis, drug delivery, hyperthermia, and magnetic resonance imaging (MRI).

Nanoparticles have high potential as antibacterial agents owing to their ability to produce reactive oxygen species (ROS) [4]. Recent studies have indicated that this ROS generation can be highly affected by the modification of band structure by the introduction of various dopant materials into them. Thus, doped nanoparticles are being extensively studied in the literature. The types of dopants, synthesis techniques, and experimental parameters have been found to have effect on the overall electronic structure of the material, leading to varied antibacterial efficiency.

Magnetic nanoparticles (MNPs) have been extensively researched and implemented in biomedicine for more than half a century due to their non-invasive nature, ease of temporal and spatial manipulation, and considerable biocompatibility. However, the complex magnetic behaviour of MNPs is influenced by several parameters (e.g., particle size, shape, composition, core-shell structure, etc.), among which the amount of transition metal doping plays an important factor. For this reason, the doping of ferrite with transition metals has been used as an effective strategy to precisely tailor MNPs to achieve satisfactory performance in biomedical applications. Nanoparticles (NPs) of metal oxide stand out in the field of antimicrobial compounds because of their catalytic inhibition activity [5].

To the best of our knowledge, there have been very few studies on antimicrobial studies of doped metal oxides. Therefore, doped metal oxides using one of the appropriate chemical, physical or green method will be synthesized for antimicrobial activities.

3. Objectives

The main objective of this synopsis is synthesis of doped metal oxides and their doping for antimicrobial activities.

- Synthesis of doped metal oxides nanostructures using sol-gel synthesis methods.
- To study structural and morphological properties of the as-prepared doped metal oxides nanostructures using various characterization techniques.
- To study antimicrobial activities of doped metal oxides.
- To study minimum inhibitory concentration (MIC).
- To study cytotoxicity activity of doped metal oxides.

4. Methodology

Doping nanoparticles on various substrates can be done by variety of methods. Many chemical, physical and biological approaches have been used for the synthesis of doped metal oxide nanoparticles. The two primary methods for producing nanosized materials include the top-down strategy (the breakdown of more prominent precursors into smaller units) and the bottom-up approach (building up smaller units to form nanosized materials). The top-down strategy employs decomposition techniques, whereas the bottom-up approach employs solvothermal approaches [6]. There are several methods in the literature for the synthesis of doped metal oxide nanoparticles such as sol-gel, arch discharge, laser ablation, chemical breakdown, sonication, dip-coating, combustion, and others have been used. The sol-gel technique has become the most extensively utilised technology because of its ease of use, product purity, and other benefits.

4.1. Synthesis of Metal Oxides

The sol-gel process is a bottom-up synthesis method. In this process, the final products are formed by performing a number of irreversible chemical reactions. During these reactions, the primary homogeneous molecules (sol) become an infinite, heavy, three-dimensional molecule called a gel.

In the sol-gel process, the conversion of sol to gel is usually done by changing the pH or changing the concentration of the solution. The main advantages of the sol-gel process are the high purity of the product, the narrow particle size distribution, and the achievement of uniform nanostructure at low temperatures. This method is commonly used to synthesize metal nano oxides. As mentioned, the solgel process involves changing the state from sol to gel using a variety of techniques; most of which use gentle drying to remove the solvent.

Since the drying of the gel is accompanied by its shrinkage, providing suitable conditions to prevent the formation of cracks is one of the most important issues in this process. The produced gel has the ability of casting and by molding and drying it is possible to produce integrated pieces. Products from casting or molding are used as filters or membranes. It is possible to create thin films with a thickness of 50–500nm by sol-gel method.

4.2. Materials characterization

A concise account of the instruments and techniques used for acknowledgement of structural, morphological and antimicrobial properties, are discussed in this section.

4.2.1 Structural studies

X-ray diffraction (XRD) technique is a one of the influential, renowned and most appropriate technique for structural revelation of materials prepared in the form of powders.

4.2.2. Fourier transform infrared spectroscopy (FT-IR)

FT-IR spectroscopy is a tool for investigation of the various chemical groups present in the sample material.

4.2.3. Morphological studies

Field Emission Scanning Electron Microscopy is a tool for investigation of the surface morphology and posture of the sample material.

4.2.4. High resolution transmission electron microscopy (HR-TEM)

HR-TEM is one of the most powerful techniques used in the characterization of Nanocomposites. It has capacity to inspect the constitutional characteristics of Nanocomposites such as grain shape and size, crystallinity and chemical variations at a nanometre scale resolution.

4.3 Antimicrobial studies

In antimicrobial studies antibacterial activity and the antifungal activity will be studied against selected species of bacteria and fungi by standard agar well diffusion method.

4.3.1 Antibacterial activity

In this study, the anti-bacterial activity of the doped metal oxide nanostructures powder will be carried out by the agar well diffusion assay. The agar will be sterilized well in an autoclave before being transferred to a petri dish to solidify. After that solidification, fresh growth of clinical isolates will be inoculated, and doped metal oxide nanostructures with various concentrations will be loaded. The zone of inhibition will be measured after the 18 to 24 h of incubation period at 37°C.

4.3.2 Antifungal activity

In this study, the antifungal activity of the doped metal oxide nanostructures powder will be tested against fungal strains using the agar well diffusion method. The PDA will be sterilized well in an autoclave before being transferred to a petri dish to solidify. After that solidification, fresh growth of clinical isolates will be inoculated, and doped metal oxide nanostructures with various concentrations will be loaded. The zone of inhibition in the antifungal assay plates will be measured after the 48 to 72 h of incubation period.

4.4 Minimum inhibitory concentration (MIC) studies

Minimum inhibitory concentration (MIC) is determined by micro-dilution plate method with Resazurin [7]. Resazurin is oxido reduction indicator use for evolution of microbial cell growth. It is blue colour non fluorescent dye which become pink fluorescent after reduction to resorufin by oxidoreductase of viable cells.

4.5 Cytotoxicity study

In this study, the synthesized doped-NPs will be tested for cytotoxicity studies by hemolysis assay. Erythrocytes will be collected from healthy humans and hemolytic activities of all synthesized doped-NPs will be determined by using human red blood cells (RBC).

The haemolysis percentage will be calculated by following formula:

$$\textbf{Haemolysis (\%)} = \frac{A^{450}\ of\ test\ compound\ treated\ sample - A^{450}\ of\ buffer\ treated\ sample}{A^{450}\ of\ 1\%\ Triton\ x\ 100\ treated\ sample - A^{450}\ of\ buffer\ treated\ sample}\ X\ 100$$

5. Importance of study

The research brings the following benefits:

Different kinds of doped-metal oxide nanostructures give insight for the development of their potential applications in the field of medicine.

6. Work plan

The proposed work will be carried out in following phases:

Phase – I (First year)

- In the first year, literature survey will be carried out. The various metal oxides will be synthesized using suitable synthesis method.

Phase – II (Second year)

- Doping of metal oxides will be carried out.
- The structural and morphological characterization carried out and analyzed.
- The antimicrobial activities will be studied using available microbes.
- MIC and cytotoxicity studies will be carried out.

Phase – III (Third year)

- The work will be communicated time to time with the high impact journals.

7. References

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